

# **EXHIBIT 22**

ENG-3476 SOFTWARE UNIT EXTERNAL FUNCTIONAL SPECIFICATION Feature: route-maps Date: 01/27/93

Version: 3.0 Author: Dino Farinacci I. Problem Definition ----- There is a customer requirement to perform route redistribution among different routing protocols based on network administrator policy. The customer wants a tool-box of conditions so they can conditionally decide which routing table entries get redistributed and what values should be set for the route in the destination routing protocol. Here are some other design motivations: o Currently, there are too many parameters on the redistribute command. This makes it hard to understand as well as support. o There are already too many combinations and new ones have been requested. o The current syntax makes it too hard to extend for new features. o With the introduction of integrated protocols it is desirable to specify which protocol suite a parameter is used for. o With the introduction of subsequent integrated routing protocols, other protocol stacks will also require "router" subcommands. So the syntax should be appropriate for any network layer protocol to reference. II. Design Considerations -----

**This design introduces some new functionality as well as expressing old functionality in a unified language.** The old syntax will be supported and the two methods will coexist. Route lists are global commands that can be referenced by other commands. This concept is similar to access lists. It allows a network administrator to configure certain criteria of a route. If a route meets this criteria the route-map is known to pass. When the route-map passes, the network administrator can specify what values should be used for redistributing a route. Route lists will have a mode similar to the "interface" and "router" commands. The route-map subcommands will be multi-line commands. There are situations that a route-map may be changed which affects redistribution behavior. When this occurs, the destination routing protocol will be informed. III. Memory and Performance Impact -----

route-maps are statically configurable lists of conditions and actions. The memory requirements grow with the number of route-maps configured. route-maps have similar memory requirements as access lists. IV. End User Interface ----- The following two commands are existing commands but have significance to route-maps. [no] router <protocol-name> <process-number|[tag]> - Same as always, accepts {IP protocol, process number} or {OSI protocol, tag}. The protocol is referred to as the "destination routing protocol" [no] redistribute <protocol-name> <process-number|[tag]> [route-map <map-tag> [<map-tag>...<map-tag>]] - **Simplified to accept a "route-map" reference.** The protocol here is referred to the "source routing protocol". If the route-map keyword is not specified, all routes from the source routing protocol are redistributed into the destination routing protocol. If the route-map keyword is specified but there is no route-map entry, routes will not be redistributed into the destination routing protocol. Otherwise, the route-map is interrogated and if all match conditions are met, the route is imported into the destination routing protocol. [no] **route-map <map-tag> [permit | deny] [<seq-num>]** - **New global command that defines the conditions for redistributing routes from one routing protocol into another.** If the conditions are met, the route is redistributed with the set values specified. - <map-tag> is used as a reference from the redistribute command. This also makes deletions easy to do. If there are multiple route-map commands with the same <map-tag>, they all can be deleted with a single command. If the <seq-num> is also specified, a single route-map entry is deleted. - [permit | deny] If the match criteria is met, and the "permit" keyword is specified, the route will be redistributed with the set criteria specified. If the match criteria is met, and the "deny" keyword is specified, the route is not redistributed. If the match criteria is not met, the next route-map with the same <map-tag> is tested. If there is none, the route is not redistributed. - <seq-num> is used primarily to insert a route-

map into an existing set, with the same <map-tag>, in a desired position. The <seq-num> can also be used to delete a specific entry of a route-map, rather than deleting them all and reentering all but the one that was meant to be deleted.

- route-map subcommands: match [ip|clns] address <access-list> [<access-list> ... <access-list>] - Any routes with address specified by standard <access-list> will be redistributed.
- match interface <name-unit> [<name-unit> ... <name-unit>] - Any routes which have a next-hop interface <name-unit> will be redistributed.
- match [ip|clns] next-hop <access-list> [<access-list> ... <access-list>] - Any routes which have a next-hop IP address specified by standard <access-list> will be redistributed.
- match [ip|clns] route-source <access-list> [<access-list> ... <access-list>] - Any routes which have been advertised by the address specified by the access list. There are situations when the next-hop and the route-source are different.
- match metric <metric-value> - Any routes with metric <metric-value> will be redistributed. The IGRP five-part metric is accepted.
- match route-type [internal | external | level-1 | level-2] - Any routes stored in the IP routing table with the following route types will be redistributed:

  - internal - OSPF intra-area and inter-area routes or IGRP2 internal routes.
  - external - OSPF external type-1 or type-2 routes or IGRP2 external routes.
  - level-1 - IS-IS level-1 routes.
  - level-2 - IS-IS level-2 routes.

- match tag <tag-value> [<tag-value> ... <tag-value>] - Any routes stored in the IP routing table with the tag equal to <tag-value> will be redistributed.
- set metric <metric-value> - If all match conditions are met, the route(s) are redistributed with a metric of <metric-value>. <metric-value> can be an IGRP five-part metric. There is no default value.
- set metric-type [type-1 | type-2 | internal | external] - If all match conditions are met, the route(s) are redistributed with the following metric types:

  - type-1 - OSPF type-1 metric.
  - type-2 - OSPF type-2 metric.
  - internal - IS-IS internal metric.
  - external - IS-IS external metric.

- There is no default value.
- set tag <tag-value> - If all match conditions are met, the route(s) are redistributed with a tag value of <tag-value>. This is true only for protocols that support tagging (i.e. OSPF, IS-IS, and IGRP2). The default value is the tag stored in the routing table.
- set level level-1 | level-2 | level-1-2 | stub-area | backbone - If all match conditions are met, the route(s) are redistributed into the following areas of the destination domain:

  - level-1 - Inserted in IS-IS level-1 LSPs.
  - level-2 - Inserted in IS-IS level-2 LSPs.
  - level-1-2 - Inserted in both level-1 and level-2 LSPs.
  - stub-area - Into OSPF Not So Stubby Areas (NSSA).
  - backbone - Into OSPF as External LSAs.

- For IS-IS the default value is level-2. For OSPF, the default value is backbone.
- set [ip|clns] destination <access-list> - If all match conditions are met, the specified destination is advertised rather than the one under evaluation. This subcommand is used to perform conditional route aggregation as well as generating default route advertisements.
- There is no default value.
- Multiple "matches" and "sets" may be specified. When all match conditions are true, all sets are performed.
- Multiple route-map commands with the same <map-tag> may be entered to provide different combinations of match/set commands.

**The route-map command and associated subcommands** can be used to support many different network layer protocols (i.e. OSI now, AppleTalk/Novell later). The "[ip|clns]" options above indicate the address type to manipulate.

Examples:

- router igrp 109 redistribute ospf 110 - Redistributions all OSPF routes into IGRP. In this case the "default-metric" command is required.
- router ospf 109 redistribute rip route-map rip-to-ospf route-map rip-to-ospf permit match metric 1 set metric 5 set metric-type type1 set tag 1 - Redistributions RIP routes with hop count equal to 1 into OSPF. These routes will be redistributed into OSPF as external link state advertisements with a metric of 5, metric type of type 1 and the tag equal to 1.
- router rip redistribute bgp 109 route-map 5 route-map 5 permit match tag 7 set metric 16 - RIP advertises BGP

learned routes with tag 7 as unreachable. ----- router  
bgp 109 redistribute ospf 109 route-map 10 route-map 10 permit match route-type internal match  
interface Serial 0 set metric 5 - OSPF intra-area and inter-area routes with next hop routers on interface  
Serial0 will be advertised by BGP with an inter-AS metric of 5. -----  
----- router isis redistribute ospf 109 route-map 2 redistribute iso-igrp nsfnet route-map 3 route-  
map 2 permit match route-type external match tag 5 set metric 5 set level level-2 route-map 3 permit  
match address 2000 set metric 30 - IS-IS is running in integrated mode. OSPF external IP routes with tag  
5 are redistributed into IS-IS and inserted in level-2 LSPs with metric 5. - Also, ISO-IGRP CLNS prefix  
routes according to CLNS access list 2000 will be redistributed into IS-IS and inserted in level-2 LSPs with  
metric 30. ----- router rip redistribute ospf 109 route-  
map 1 route-map 1 permit match tag 1 2 set metric 1 route-map 1 permit match tag 3 set metric 5  
route-map 1 deny match tag 4 route-map 1 permit match tag 5 set metric 5 - OSPF external routes with  
tag 1, 2, 3, and 5 are redistributed into RIP with metrics 1, 1, 5, and 5 respectively. A OSPF route with tag  
of 4 is not redistributed. ----- router rip redistribute  
ospf 109 route-map default route-map default permit match ip address 1 set ip destination 2 set metric  
1 access-list 1 permit 140.222.0.0 0.0.255.255 access-list 2 permit 0.0.0.0 0.0.0.0 - If there exists an OSPF  
route to network 140.222.0.0, generate the default network into RIP with metric 1. -----  
----- router isis redistribute rip route-map 1 redistribute iso-igrp remote  
route-map 1 route-map 1 permit match ip address 1 match clns address 2 set metric 5 set level level-2  
access-list 1 permit 160.89.0.0 0.0.255.255 clns filter-set 2 permit 49.0001.0002... - A RIP learned route  
for network 160.89.0.0 and an ISO-IGRP learned routes with prefix 49.0001.0002 are redistributed into  
an IS-IS level-2 LSP with metric 5. ----- VI. Testing  
Considerations ----- To test route-maps, as little as three routers may be used. 1 router  
generating routing updates for routing protocol A, 1 router for generating routing updates for routing  
protocol B, and a router in the middle that runs both protocols and redistributes between the two. The  
conditions for redistribution can be configured with the route-maps. Using debug output, one can  
determine if a route was redistributed based on the match requirements set by the route-maps. Then,  
the protocol that redistributes can be examined to see if the set requirements set by the route-maps  
were performed correctly. To test the syntax code for route-maps, a single router may be used. VII.  
Reference Documents ----- None.